Project Number 001907

DELIS
Dynamically Evolving, Large-scale Information Systems

Integrated Project
Member of the FET Proactive Initiative Complex Systems

Deliverable D0.03

Report on Workshop and Achievements of Cross-Cutting Topic 1

Peer-to-Peer Based Data Management
Start date of the project: January 2004
Duration: 48 months
Project Coordinator: Prof. Dr. math. Friedhelm Meyer auf der Heide
Heinz Nixdorf Institute, University of Paderborn, Germany
Due date of deliverable: December 2005
Actual submission date: February 2006
Dissemination level: PU – public

Cross-Cutting Topic 1: Peer-to-Peer Based Data Management
Participants: Friedhelm Meyer auf der Heide, Christian Schindelhauer (UPB)
Giovanni Cortese (TILS)
Stefano Leonardi (UDRLS)
Gerhard Weikum (MPII)

Author of deliverable: Giovanni Cortese (g.cortese@ipsoft.it)
1 Introduction

This document is the report of the activities of CCT 1 in the second year of the DELIS project. The organisation of the document is as follows. Firstly, we summarize the objectives of the CCT. We then report on meetings and workshops related to the CCT, which also highlight directions for future work in the area. Last, we provide a summary of the deliverables and technical reports which are relevant to this cross-cutting topic.

2 Objectives of Cross-Cutting Topic 1

Objectives and scope of CCT 1, as described in the Implementation Plan for Months 13 – 30 are as follows. In a peer-to-peer system, each node has the role of both a server and a client, i.e., it both offers and requests resources shared by the system. Such systems tend to be very large and exhibit a significant dynamic to new nodes joining and existing nodes leaving the system.

Keeping such a system functioning, controlling, and optimizing it therefore cannot be done in a centralized way; rather decentralized, local strategies are needed that result in a globally acceptable behavior of the system. Within DELIS we have started and will continue to develop such techniques, and will use them in our data management platform for network management and in our decentralized, self-organizing Web search engine. We tackle problems arising in designing, monitoring, and controlling peer-to-peer systems under different points of view, originating from a variety of different approaches and expertise. We will combine this body of insights and methods and examine it with respect to its potential for improving the capabilities, the reliability, and the performance of our peer-to-peer based network management platform and Web search engine.

Specific areas being investigated are:

- Peer-to-peer network design for complex systems,
- Distributed Hash Tables or alternative data structures,
- Strategies for routing queries to other peers and exchanging meta data,
- Data stream processing in peer-to-peer environment,
- Collaborative Web information search,
- Meta search and distributed rank aggregation,
- Distributed storage and query techniques for semantic frameworks, and

The peer-to-peer Web search engine pursued in SP6 is right in the core of this CCT. As an application-driven task, SP6 contributes to this CCT by assessing the practical viability of the peer-to-peer methods. Conversely, SP6 will shed deeper light into the requirements posed on the underlying peer-to-peer system and its constituents such as advanced DHTs and graph-based overlay networks or routing and collaboration strategies. To this end, SP6 will provide an experimental testbed to Delis that can be used for trying out new algorithms and strategies and for studying their interplay in a complex system, at different levels and different time scales.

SP2 contributes to the CCT with research and implementation work on a peer-to-peer network management platform. Research here is driven at large by the requirements of applications such as decentralized information directories, and distributed data collection for monitoring purposes. This platform poses different challenges to peer-to-peer techniques with respect to SP6, e.g., it
asks for strategies for organizing and searching structured (or semi-structured) data as opposed to unstructured Web data, as considered in SP6. It also requires query processing and peer-to-peer storage techniques which are specific to the type of applications, also requiring somehow stronger guarantees in terms of search result accuracy than in the P2P web search activities.

In SP2, testbed-based evaluation for data oriented P2P overlays is also a concern, and investigation of methodologies and tools supporting this task will be done.

SP1 is researching neighbor discovery algorithms in peer-to-peer networks.

This can be extended to contribute to “Strategies for routing queries to other peers and exchanging meta data”. An analysis of various routing algorithms in peer-to-peer protocols will also be included in our Testbed experiments. The activities of WP1.3 will in general contribute to a better understanding of “peer-to-peer network design for complex systems”.

SP3 and SP4 contribute fundamental research which can be leveraged by the more oriented research in SP2 and SP6.

SP3 develops approximative, heuristic and exact algorithms for routing, load balancing and data mining problems in large networks. Many of these problems are fundamental for peer-to-peer based data management. We expect that the research in SP3 will provide significant results to optimize and to control peer-to-peer systems. SP4 contributes a new paradigm of selfish peer-to-peer network architectures.

Biologically and sociologically inspired strategies for dissemination and self-organization will greatly contribute to the networking layer in peer-to-peer data management. Collaboration strategies for organizing and searching both structured data (as considered in SP2) and unstructured Web data (as considered in SP6) can leverage the insights from SP5 for dynamic spreading of data, metadata, statistical summaries, and user requests in evolutionary networks.

3 CCT 1 Workshop and Meetings

A first meeting was held in Saarbrücken, jointly with the SP6 meeting, with participation and invited talks from SP2 (Giovanni Cortese and Felix Heine). A second meeting involving people in this CCT was held in Paris, November 17th, 2005, in the context of 2nd European Conference on Complex Systems (ECCS’05) in Paris which is extensively reported now.

3.1 Workshop: Peer-to-Peer Data Management in the Complex Systems Perspective

This section summarizes indications originated from workshop presentations, and from the following discussion among workshop participants, which could be relevant to the ONCE-CS effort. The workshop was organized by DELIS researchers involved in the CCT 1 working group. For the scope of the workshop, please refer to http://delis.upb.de/p2p-complex-05-prg.html. Overall, the workshop called for contributions on the research topics mentioned above.

The workshop was chaired by Christian Schindelhauer and Giovanni Cortese.

3.1.1 Workshop Presentations

<table>
<thead>
<tr>
<th>Presenter</th>
<th>Danny Bickson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authors</td>
<td>Danny Bickson, joint work with Karl Aberer, Danny Dolev, Manfred Hauswirth, and Yair Weiss</td>
</tr>
<tr>
<td>Title</td>
<td>Data Indexing in Overlay Networks using the Belief Propagation Algorithm</td>
</tr>
</tbody>
</table>
For all four presentations, the extended abstracts are published in the 3rd DELIS Newsletter which was distributed at ECCS in Paris among the participants.

### 3.1.2 Summary of Workshop Discussions

A discussion was held among the workshop participants after the presentations, which is reported in the remainder of this section.

Quite obviously, all participants to the discussion agreed in the first place that the topic of P2P data management is highly relevant to complex systems research. The relationship is ‘bi-directional’ in that (1) large scale P2P data-oriented systems are inherently complex systems (i.e., analyzing and understanding their behavior requires complex systems tools), and (2) engineering current and future P2P data management infrastructures requires theoretical tools and techniques, which are researched in the complex systems community.

### 3.1.3 Visions for P2P Data Management in Complex Systems research

Researcher working on peer-to-peer data management are motivated by different long-term goals or visions. Such diversity of goals was apparent even in the small group such as that attending the workshop.

Reported long term goals or ‘visions’ follow, as described by researchers at the workshop.

- **Fully p2p Internet Search and Information Retrieval** — to defeat Google or other information monopolies.
- **Self.* peer-to-peer data management middleware** — to create data management systems based on collaboration of many decentralised nodes, which do not require any human intervention for configuring, optimizing, monitoring, troubleshooting. Examples: autonomic, decentralized data storage and query facilities; self-optimising publish-subscribe, data dissemination infrastructures.
- The P2P network-based virtual workplace — to support, with adequate performance, all needs for (personal) computing through a peer to peer approach. Again defeating monopolies is a driver here.

While the items above propose an application-oriented vision, it was also recognized in the panel that from a more technical point of view all of the above require a dramatic advance in supporting technology, i.e.

- Improve our ability to implement a variety of P2P data structures as fundamental mechanisms to support more advanced data management services.

### 3.1.4 Research Challenges

This section collects a number of research challenges, which were identified as required steps towards realizing the visions above (no ranking among them implied by the order they appear).

**Self-organisation** Self-organisation has probably been from the beginning the most distinguishing feature of P2P systems. In the context of P2P data management, specific issues such as optimality in data placement, load balancing, autonomic adaptation of the system to changing load pattern still deserve fundamental research.

Still related to adaptivity of peer-to-peer systems, a point was raised about the need of creating P2P systems which are adaptable to the behaviour of different groups of users. This kind of adaptivity depends both on user behaviour modelling, and on design methods accounting for adaptivity and ultimately, ‘intelligence’ of a P2P system (possible examples endowing it with ability to change strategies for caching, replication etc based on the population of users).

**Decentralised statistics** Decentralised statistics is a key enabler of scalable, self-optimizing peer-to-peer systems. It is required both as a key component for realising decentralised database middleware, and large-scale information retrieval systems. Also, workable approaches to distributed logging and ‘debugging’ of P2P system behaviour are required.

**Relationships between layers of the system** One of the presentations raised clearly the need for a better understanding of the relationships between the underlay and the overlay network. Not much research has been devoted to this issue, and models and metrics to explain this relationship to help with design of overlays are lacking so far.

Also, it is correct to mention that a further area of research is the dependency of the data management overlay and the routing topology. Such research should be backed by proper simulation technologies and tools.

**Economy of p2p data management** From a different respect, a better understanding of user behaviour is required to explain/ foster adoption of peer-to-peer systems. An example was presented (the DIMES project), to illustrate mechanisms related to successful spreading of a P2P service. Specific topics for research include studying incentives for resource sharing and user participation (not forgetting about economics from the point of view of the ISPs).

### 4 Summary of Research in CCT 1

Main contributions to activities in this area are from SP1, SP2 and SP6.

SP2 contributed several activities specific to implement a large scale data management system geared towards handling of (semi)structured data and queries with highest possible precision and recall.
Driving applications for SP2 are information directories and distributed monitoring, which are needed in network and systems management. SP2 focus is on supporting peer-to-peer storage, replication and dissemination of XML/RDF data, search mechanisms able to retrieve (as far as possible in a dynamic system) all results matching user queries, and dissemination of query results to many interested clients. Ability to process taxonomic reasoning in user queries (using the semantic web representation languages – RDFS) is also a research topic addressed. This is motivated by the desire to process queries in a scenario where peers use different schema or ontologies to model their data. Last, continuous, stream-oriented queries are also relevant to the motivating application scenario. SP2 activities related to peer-to-peer data management are documented in the deliverable D2.3.2 “Next-Generation Management Platform-Architecture, Algorithms and Prototypes” and D2.4.3 “Testbed-based experimental evaluation of application prototypes”; and in 3 DELIS Technical Reports:

- DELIS TRs [DELIS-TR-0228], [DELIS-TR-0229] describe an adaptive content-based subscription management scheme in DHT-based overlay networks,
- DELIS TR [DELIS-TR-0208] describes data dissemination and query processing algorithms for semi-structured data in p2p environments,
- Publish-subscribe in dynamic systems (included in D2.3.2) — describes data dissemination using unstructured overlay networks and gossip.

SP6 focus is on peer-to-peer information retrieval. SP6 adopts the P2P approach to store in the network large index information. Given the targeted application, SP6 uses search and query techniques which privilege extreme scalability, while the ability of returning all query results is a lesser concern. Ranking of results is instead an important concern.

Both SP2 and SP6 currently research and build on top of structured overlays; they have also started researching techniques based on random topologies as a way to improve overlay robustness in face of high dynamism.

A selection of 2005 research in SP6 addressing data management in peer-to-peer networks follows:

- Query processing in structured overlays — [DELIS-TR-0144] Load Distribution and Range Query Processing in Peer-to-Peer Data Networks
- Privacy protection in P2P networks — [DELIS-TR-0169], [DELIS-TR-0210]

SP1 contributed in the area of research related to understanding the relationships of the underlay and overlay network. Main partner in SP1 contributing to this CCT is TUM. Activities are documented in Deliverable D1.3.2 and D1.3.3; and DELIS Technical Report [DELIS-TR-0193].

• Vinay Aggarwal and Anja Feldmann. *Setting up a realistic Testlab reflecting real P2P behaviour and development of a mechanism to validate the results from SSFnet simulations in the Testlab.* DELIS Deliverable D1.3.3, December 2005.

Still related to P2P, SP1 also researches neighbor discovery algorithms in P2P networks, although this is less related to data management and addresses more lower layer issues.